A | Reissue

| REISSUE **PATENT APPLICATION TRANSMITTAL** (Large Entity) *(Only for new nonprovisional applications under 37 CFR 1.53(b))* | Docket No. XA-7521D Re |
| | Total Pages in this Sub |

TO THE ASSISTANT COMMISSIONER FOR PATENTS
Box Patent Application
Washington, D.C. 20231

Transmitted herewith for filing under 35 U.S.C. 111(a) and 37 C.F.R. 1.53(b) is a reissue patent application for an invention entitled:

> PROJECTION EXPOSURE APPARATUS

and invented by:

> Kazuo USHIDA – Tokyo, Japan
> Masaomi KAMEYAMA – Tokyo, Japan

If a CONTINUATION APPLICATION, *check appropriate box and supply the requisite information:*

☒ **Continuation**   ☐ **Divisional**   ☐ **Continuation-in-part (CIP)**   of prior application No.: 09/103,536

Which is a:

☒ **Reissue**   ☐ **Divisional**   ☐ **Continuation-in-part (CIP)**   of Patent No. : 5,530,518

Which is a:

☐   ☐ **Divisional**   ☐ **Continuation-in-part (CIP)**   of prior application No.: _____

Enclosed are:

Application Elements

1. ☒ Filing fee as calculated and transmitted as described below

2. ☒ Specification having _____28_____ pages and including the following:

   a. ☒ Descriptive Title of the Invention

   b. ☐ Cross References to Related Applications *(if applicable)*

   c. ☐ Statement Regarding Federally-sponsored Research/Development *(if applicable)*

   d. ☐ Reference to Microfiche Appendix *(if applicable)*

   e. ☒ Background of the Invention

   f. ☒ Brief Summary of the Invention

   g. ☒ Brief Description of the Drawings *(if drawings filed)*

   h. ☒ Detailed Description

   i. ☒ Claim(s) as Classified Below

   j. ☒ Abstract of the Disclosure

UTILITY PATENT APPLICATION TRANSMITTAL
(Large Entity)
(Only for new nonprovisional applications under 37 CFR 1.53(b))

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Application Elements (Continued)

3. ☒ Drawing(s) *(when necessary as prescribed by 35 USC 113)*

    a. ☒ Formal   Number of Sheets   8

    b. ☐ Informal   Number of Sheets

4. ☒ Oath or Declaration

    a. ☐ Newly executed *(original or copy)*   ☐ Unexecuted

    b. ☒ Copy from a prior application (37 CFR 1.63(d)) *(for continuation/divisional application only)*

    c. ☐ With Power of Attorney   ☐ Without Power of Attorney

    d. ☐ *DELETION OF INVENTOR(S)*
    Signed statement attached deleting inventor(s) named in the prior application,
    see 37 C.F.R. 1.63(d)(2) and 1.33(b).

5. ☒ Incorporation By Reference *(usable if Box 4b is checked)*
The entire disclosure of the prior application, from which a copy of the oath or declaration is supplied under Box 4b, is considered as being part of the disclosure of the accompanying application and is hereby incorporated by reference therein.

6. ☐ Computer Program in Microfiche *(Appendix)*

7. ☐ Nucleotide and/or Amino Acid Sequence Submission *(if applicable, all must be included)*

    a. ☐ Paper Copy

    b. ☐ Computer Readable Copy *(identical to computer copy)*

    c. ☐ Statement Verifying Identical Paper and Computer Readable Copy

Accompanying Application Parts

8. ☐ Assignment Papers *(cover sheet & document(s))*

9. ☒ 37 CFR 3.73(B) Statement *(when there is an assignee)* (copy from prior application)

10. ☐ English Translation Document *(if applicable)*

11. ☐ Information Disclosure Statement/PTO-1449   ☐ Copies of IDS Citations

12. ☐ Preliminary Amendment

13. ☒ Acknowledgment postcard

14. ☐ Certificate of Mailing

    ☐ First Class   ☐ Express Mail *(Specify Label No.):*

    P01ULRG/REV04

UTILITY PATENT APPLICATION TRANSMITTAL
(Large Entity)
(Only for new nonprovisional applications under 37 CFR 1.53(b))

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Accompanying Application Parts (Continued)

15. ☐ Certified Copy of Priority Document(s) *(if foreign priority is claimed)*

16. ☒ Additional Enclosures *(please identify below)*:

- Offer to Surrender, Assent of Assignee and Power of Attorney (copy from prior application)
- Request for Transfer of Drawings
- Claim of Priority

Fee Calculation and Transmittal

CLAIMS AS FILED

For	#Filed	#In Patent	#Extra	Rate		Fee
Total Claims *	138	-25 =	113	x	$18.00	2,034.00
Indep. Claims **	15	-7 =	8	x	$78.00	624.00
Multiple Dependent Claims (check if applicable) ☒						260.00
*In excess of 20 and patent ** In excess of Patent					BASIC FEE	760.00
OTHER FEE *(specify purpose)*						
					TOTAL FILING FEE	$3,678.00

☒ A check in the amount of $3,678.00 to cover the filing fee is enclosed.

☒ The Commissioner is hereby authorized to charge and credit Deposit Account No. 22-0585 as described below. A duplicate copy of this sheet is enclosed.

   ☐ Charge the amount of   as filing fee.

   ☒ Credit any overpayment.

   ☒ Charge any additional filing fees required under 37 C.F.R. 1.16 and 1.17.

   ☐ Charge the issue fee set in 37 C.F.R. 1.18 at the mailing of the Notice of Allowance, pursuant to 37 C.F.R. 1.311(b).

Signature

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Dated: May 25, 1999

CC:

P01ULRG/REV04

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

In re the Application of:

Kazuo USHIDA et al.

Appln. No.:

Filed: HEREWITH

For: PROJECTION EXPOSURE APPARATUS

* * *

PRELIMINARY REMARKS

Assistant Commissioner for Patents
Washington, D.C. 20231

Sir:

The present continuation application has been filed in order to preserve Applicants' rights under 35 U.S.C. § 135 with respect to U.S. Patent No. 5,757,470 issued May 26, 1998 (the '470 patent).

Claims 26-29 are carried over from the parent application. Claims 30-67 have been copied substantially (in most cases exactly) from the '470 patent. Claims 68-90 are based on the claims of the European counterpart of the '470 patent, EP 0 648 348 B1.

The Commissioner is hereby authorized to charge to Deposit Account No. 22-0585 any fees under 37 C.F.R. §§ 1.16 and 1.17 that may be required by this paper and to credit any overpayment to that Account. If any extension of time

is required in connection with the filing of this paper and has not been requested separately, such extension is hereby requested.

Respectfully submitted,

By: _Mitchell W. Shapiro_
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MWS:lmb

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May 25, 1999

PROJECTION EXPOSURE APPARATUS

This is a continuation of application Ser. No. 08/274,369 filed Jul. 13, 1994, which is a continuation-in-part of application Ser. No. 08/166,153 filed Dec. 14, 1993, which is a continuation of application Ser. No. 07/991,421 filed Dec. 16, 1992, all now abandoned.

BACKGROUND OF THE INVENTION

1. Field of the Invention

This invention relates to a projection exposure apparatus for projection-exposing minute patterns necessary for the manufacture of semiconductive integrated circuits or the like onto a substrate (wafer).

2. Related Background Art

As a prior-art projection exposure apparatus, there is known one in which exposure light is applied to a projection negative such as a mask or a reticle (hereinafter referred to as the reticle) on which a circuit pattern is formed, and the image of the circuit pattern on the reticle is transferred onto a substrate such as a wafer (hereinafter referred to as the wafer) through a projection optical system.

Here, resolving power representative of a line and space pattern transferred onto the wafer is theoretically of the order of $0.5 \times \lambda \times NA$ when the wavelength of the exposure light is λ and the numerical aperture of the projection optical system is NA.

In the actual lithography process, however, a certain degree of depth of focus becomes necessary due to the influence of the curvature of the wafer, the level difference of the wafer by the process, etc. or the thickness of photoresist itself. Therefore, practical resolving power to which a factor such as the depth of focus has been added is expressed as $k \times \lambda \times NA$, where k is called a process coefficient and is usually of the order of 0.7–0.8.

Now, in recent years, particularly the tendency toward the minuteness of patterns transferred onto wafers is advancing and as a technique for coping with this tendency toward the minuteness, it is conceivable to shorten the wavelength of exposure light or to increase the numerical aperture NA of the projection optical system, as is apparent from the above-expression of the resolving power.

However, in the technique of shortening the wavelength of exposure light, glass materials usable for the lenses of the projection optical system become limited with the shortening of the exposure light, and it is difficult to design a projection optical system in which aberrations have been sufficiently corrected, in such limited glass materials.

Also, in the technique of increasing the numerical aperture NA of the projection optical system, an improvement in resolving power can be surely achieved, but the depth of focus of the projection optical system is inversely proportional to the square of the numerical aperture NA of the projection optical system. Accordingly, the depth of focus decreases remarkably, and this is not preferable. Moreover, it is difficult to design a projection optical system which has a great numerical aperture NA and yet in which aberrations have been sufficiently corrected.

SUMMARY OF THE INVENTION

So, it is an object of the present invention to eliminate the above-noted problems and to provide a projection exposure apparatus in which the depth of focus of a projection optical system is improved, whereby in practical use, a circuit

pattern on a reticle can be faithfully transferred onto a wafer with a higher resolution.

To achieve the above object, a projection exposure apparatus according to an embodiment of the present invention includes illuminating optical means for illuminating a projection negative, and projection optical means for projection-exposing the projection negative illuminated by the illuminating optical means onto a substrate, the illuminating optical means including light source means for supplying exposure light, annular light source forming means for forming an annular secondary light source by the light from said light source means, and condenser means for condensing the light beam from said annular light source forming means on the projection negative, and is designed to satisfy the following condition:

$$\tfrac{1}{3} \leq d_1/d_2 \leq \tfrac{2}{3}, \tag{1}$$

where d_1 is the inner diameter of the annular secondary light source, and d_2 is the outer diameter of the annular secondary light source.

As described above, the projection exposure apparatus according to an embodiment of the present invention is designed to illuminate the reticle by the exposure light from the light source means, i.e., effect so-called annular illumination (or inclined illumination).

At this time, the annular secondary light source of the annular light source forming means is designed to satisfy the above-mentioned conditional expression (1), whereby the depth of focus of projection means can be improved to achieve an improvement in practical resolution.

When as an example, the wavelength λ of light source means is i-line (365 nm) and the wafer side numerical aperture NA of a projection lens is 0.4, the line width which can be resolved by a prior-art exposure apparatus in which the process coefficient is 0.7 is of the order of 0.64 μm from $k \times \lambda/NA$, while in the projection exposure apparatus according to an embodiment of the present invention, the process coefficient k is of the order of 0.5 and therefore, the line width which can be resolved is 0.46 μm. Thus, it will be seen that in the projection exposure apparatus according to the present invention, an improvement in resolution after a practically more sufficient depth of focus than in the prior-art apparatus has been secured is achieved.

If the lower limit of the above condition (1) is exceeded, the inner diameter of the annular second light source becomes too small, and the effect or advantage caused by the annular illumination according to the invention is reduced so that it is difficult to improve depth of focus as well as resolution of the projection optical system.

If the upper limit of the condition (1) is exceeded, the width of each line forming a pattern or patterns on a reticle, which width is uniform and the same, becomes uneven or varied depending on repetition of the lines or line-to-line distances of the pattern when transferred onto the wafer, and accordingly it is not possible to transfer the pattern on the reticle onto the wafer accurately.

Further, if the upper limit of the condition (1) is exceeded, change in line width for change in exposure amount is enlarged and it is difficult to form a pattern of a desired line width on the wafer.

Further, to sufficiently bring out the effect of annular illumination according to the present invention, it is desirable that when the projection negative side numerical aperture of the projection optical means is NA_1 and the numerical aperture of the illuminating optical means determined by the outer diameter of the annular secondary light source is NA_2, the projection exposure apparatus according to the

present invention be designed to the following conditional expression (2):

$$0.45 \leq NA_2/NA_1 \leq 0.8 \qquad (2)$$

If the lower limit of this conditional expression (2) is exceeded, the angle of incidence of the light which inclination-illuminates the reticle by annular illumination will become small and the effect of annular illumination according to the present invention can hardly be obtained. Therefore, effecting annular illumination will become meaningless in itself.

If conversely, the upper limit of conditional expression (2) is exceeded, the resolution as a spatial image will be improved, but the depth of focus will be reduced. Further, the contrast at the best focus will be greatly reduced, and this is not preferable.

As described above, in the projection exposure apparatus according to the present invention, a depth of focus greater than in the prior-art projection exposure apparatus can be secured and therefore, exposure under a practically higher resolution can be realized. Thereby, more minute patterns than in the prior-art projection exposure apparatus can be transferred onto wafers.

Other objects, features and effects of the present invention will become fully apparent from the following detailed description taken in conjunction with the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a schematic view schematically showing the construction of a first embodiment of the present invention.

FIG. 2 is a plan view showing the construction of an aperture stop.

FIG. 3 shows the opening portion of an aperture stop provided at the pupil position of a projection optical system.

FIG. 4 schematically shows a modification of the first embodiment of the present invention.

FIG. 5 schematically shows the construction of a second embodiment of the present invention.

FIG. 6 shows the construction of a turret in the second embodiment of the present invention.

FIG. 7 schematically shows a modification of the second embodiment of the present invention.

FIG. 8 is a schematic view schematically showing the construction of a third embodiment of the present invention.

FIG. 9 is a schematic view showing a light guide in the third embodiment of the present invention.

FIG. 10 shows a modification of the first embodiment of the present invention.

FIG. 11 shows a modification of the first embodiment of the present invention.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

Some embodiments of the present invention will hereinafter be described with reference to the drawings.

FIG. 1 schematically shows the construction of a first embodiment of the present invention, and the first embodiment of the present invention will hereinafter be described in detail with reference to FIG. 1.

Light (for example, light of g-line (436 nm), i-line (365 nm) or the like) from a mercury arc lamp 1 is condensed by an elliptical mirror 2 and is converted into a parallel light

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beam by a collimator lens 4 via a reflecting mirror 3. Thereafter, when the parallel light beam passes through a fly-eye lens 5 (optical integrator) comprised of an aggregate of a plurality of bar-like lens elements, a plurality of light
5 source images are formed on the exit side thereof corresponding to the number of the bar-like lens elements constituting the fly-eye lens 5.

An aperture stop 6 having an annular transmitting portion is provided at a location whereat the secondary light source
10 is formed, and here is formed an annular light source.

The aperture stop 6, as shown in FIG. 2, is formed by the deposition of light intercepting portions 6b and 6c of chromium or like material so that for example, an annular transmitting portion 6a may be formed on a transparent
15 substrate such as quartz. Alternatively, the aperture stop 6 may be comprised of a circular light intercepting member and a light intercepting member having a circular opening larger than that.

When here, the diameter of the light intercepting member
20 6b of the aperture stop 6 (the inner diameter of the annular transmitting portion 6a) is d_1 and the diameter of the light intercepting member 6c of the aperture stop 6 (the outer diameter of the annular transmitting portion 6a) is d_2 and d_1/d_2 is defined as an annular ratio, the annular ratio of the
25 aperture stop 6 is designed within a range of ⅓ to ⅔.

Now, the light from the annular secondary light source formed by the aperture stop 6 is condensed by a condenser lens 8 via a reflecting mirror 7 and superposedly uniformly illuminate a circuit pattern 9a on a reticle 9 from an oblique
30 direction. Thereupon, the image of the circuit pattern on the reticle 9 is formed on the exposure area of a wafer 11 by a projection optical system 10. Accordingly, resist applied onto the wafer 11 is sensitized and the image of the circuit pattern on the reticle 9 is transferred thereto.

35 Thereafter, the projection exposure apparatus drives a stage 12 on which the wafer 11 is placed, and moves the wafer 11 so that the circuit pattern can be transferred to an area discrete from the afore-mentioned exposure area. The illuminated circuit pattern on the reticle 9 is then transferred
40 by the projection optical system 10. In this manner, the projection exposure apparatus transfers circuit patterns in succession onto the wafer 11.

An aperture stop 10a is provided at the position of the pupil (entrance pupil) of the projection optical system 10,
45 and this aperture stop 10a is provided conjugately with the aperture stop 6.

FIG. 3 shows the state of the circular opening portion P of the aperture stop 10a, and as shown, the image I of the annular secondary light source is formed inside the opening
50 portion A of the aperture stop 10a, and the annular ratio of the image I of this secondary light source (the inner diameter D_1 of the image of the secondary light source/the outer diameter D_2 of the image of the secondary light source) is
55 equal to the above-mentioned annular ratio of the aperture stop 6.

When here, the diameter of the opening portion of the aperture stop 10a is D_3, the ratio (D_2/D_3) of the outer diameter of the image of the secondary light source to the
60 diameter of the opening portion A of the aperture stop 10a is called a coherence factor, i.e., σ value, and at this time, the image I of the annular secondary light source is formed within the range of the σ value of 0.45 to 0.8, as shown in FIG. 3.

65 When as shown in FIG. 1, the reticle side numerical aperture of the projection optical system 10 determined by a ray R_1 from the most marginal edge of the aperture stop

10a which is parallel to the optical axis Ax is NA_1 ($=\sin\theta_1$) and the numerical aperture of the illuminating optical system (1–8) determined by a ray R_2 from the most marginal edge (the outermost diameter) of the aperture stop 6 which is parallel to the optical axis Ax is NA_2 ($=\sin\theta_2$), the σ value is also defined by the following equation:

$$\sigma = NA_2/NA_1$$

Now, in the process of printing a circuit pattern on the wafer 11, there are various processes such as a process in which the printing of a minute pattern is required, and a process in which a great depth of focus is required, and the optimum depth of focus and resolution in each of these processes are found.

Therefore, in the present embodiment, the aperture of the aperture stop 10a is variably designed and the σ value is varied to thereby control the depth of focus and resolution on the wafer 11.

A desired depth of focus and resolution are first input by means of an input portion 16 such as a keyboard. A control portion 14 determines the σ value on the basis of this input information, and controls a driving portion 15 for varying the aperture of the aperture stop 10a. The driving portion 15 varies the diameter of the opening portion A of the aperture stop 10a and changes the σ value.

Also, as shown in FIG. 4, a mark 9b such as a bar code including process information, the information of the desired depth of focus and information regarding a minimum line width on the wafer 11 may be provided on the reticle 9, and a mark detecting portion 13 for detecting this mark 9b may be provided. In this case, the control portion 14 determines the σ value on the basis of information detected by the mark detecting portion 13.

As described above, in the present embodiment, annular illumination is effected by the disposition of the aperture stop 6 and therefore, greater improvements in the depth of focus and resolution can be achieved. Further, the σ value is variable and therefore, an optimum illuminating condition conforming to each process can be achieved.

Also, in the embodiments shown in FIGS. 1 and 4, the aperture stop 6 is fixedly used, but the annular ratio of this aperture stop 6 may be varied. FIG. 5 is a schematic view schematically showing the construction of a second embodiment in which a plurality of aperture stops differing in annular ratio from one another are provided along the circumferential direction of a circular substrate (turret).

In FIG. 5, for the simplicity of illustration, members functionally similar to those in the first embodiment shown in FIG. 1 are given the same reference characters.

Only the differences of the second embodiment from the first embodiment will hereinafter be described in detail. In the projection exposure apparatus shown in FIG. 5, a circular substrate 60 provided with a plurality of aperture stops having different annular ratios is provided at a position on the exit side of the fly-eye lens 5 whereat a plurality of light source images are formed. As shown in the plan view of FIG. 6, a first group of aperture stops (60b–60c) having different annular ratios within a range of ⅓–⅔ and a second group of aperture stops (60f–60h) having an outer diameter differing from that of the first group of aperture stops and having different annular ratios within a range of ⅓–⅔ are provided on the transparent circular substrate 60 by the deposition of chromium or the like. Further, a circular aperture stop 60a having the same diameter as the outer diameter of the first group of aperture stops and a circular aperture stop 60e having the same diameter as the outer diameter of the second group of aperture stops are provided on the circular substrate 60.

In the present embodiment, the aperture stops ($60b$–$60c$, $60f$–$60h$) having optimum annular ratios are set on the exit side of the fly-eye lens 5 and the depth of focus and resolution on the wafer 11 are controlled.

Turning back to FIG. 5, the control of the above-mentioned depth of focus and resolution will hereinafter be described in detail.

Process information and information regarding the required depth of focus and minimum line width are input by the use of the input portion 16 such as a keyboard.

On the basis of such input information, the control portion 14 selects one of the aperture stops ($60b$–$60c$, $60f$–$60h$). The control portion 14 then controls a driving portion 61 for driving the circular substrate 60 so that the selected one of the aperture stops ($60b$–$60c$, $60f$–$60h$) may be positioned on the exit side of the fly-eye lens 5.

Thereby, the depth of focus and resolution on the wafer 11 can be controlled and therefore, optimum annular illumination under an optimum σ value can be accomplished. Also, if the aperture stops ($60a$, $60e$) having an usual circular opening are set on the exit side of the fly-eye lens 5, exposure by usual illumination can be accomplished.

Also, as shown in FIG. 7, a mark $9b$ such as a bar code including process information and information regarding the desired depth of focus and minimum line width on the wafer 11 may be provided on the reticle 9 and a mark detecting portion 13 for detecting this mark $9b$ may be provided. In such case, the control portion 14 selects one of the aperture stops ($60b$–$60c$, $60f$–$60h$) on the basis of information detected by the mark detecting portion 13.

A third embodiment of the present invention will now be described with reference to FIGS. 8 and 9. FIG. 8 is a schematic view schematically showing the construction of the third embodiment of the present invention. For simplicity of illustration, members functionally similar to those in the first embodiment of FIG. 1 are given the same reference characters.

The difference of the third embodiment from the first embodiment is that instead of the aperture stop 6 provided between the fly-eye lens 5 and the reflecting mirror 7, there are provided a condensing lens 20 and a light guide 21 comprised of a plurality of optical fibers having their entrance sides bundled into a circular shape and having their exit sides bundled into an annular shape, and a number of annular light sources are formed without intercepting a light beam from the fly-eye lens 5.

In the third embodiment of FIG. 8, a plurality of light source images are formed on the exit side of the fly-eye lens 5 by the light from the mercury arc lamp 1 through the intermediary of the elliptical mirror 2, the reflecting mirror 3, the collimator lens 4 and the fly-eye lens 5 in succession. Since the exit end of the fly-eye lens 5 and the exit end of the light guide 21 are made into a conjugate relation by the condensing lens 20, an annular secondary light source is formed at the exit end of the light guide 21.

As shown in FIG. 9, a circular member $21a$ for bundling a plurality of fibers is provided at the entrance end of the light guide 21 and an annular member $21b$ for bundling the plurality of fibers into an annular shape is provided at the exit end of the light guide.

The ratio of the inner diameter of the exit end of the light guide 21 to the outer diameter of the exit end of the light guide 21, i.e., the annular ratio, is designed so as to be ⅓ to ⅔, and as shown in FIG. 3, an annular light source image of which the σ value is of the order of 0.45 to 0.8 is formed at the position of the aperture stop $10a$ of the projection optical system.

By the above-described construction, in the present embodiment, annular illumination can be effected efficiently without intercepting the light from the light source 1 and therefore, not only greater improvements in the depth of focus and resolution can be achieved, but also exposure 5 under a high throughput can be accomplished.

Again in the present embodiment, as described above, means for detecting a mark including various kinds of information on the reticle may be provided and on the basis of the information detected thereby, the optimum diameter 10 of the opening portion of the aperture stop 10a may be set, and annular illumination under an optimum σ value may be effected.

Further, in the present embodiment, provision may be made of a plurality of light guides differing in annular ratio 15 and outer diameter from one another and design may be made such that in conformity with the required depth of focus and resolution, one of the plurality of light guides is positioned between the condensing lens 20 and the condenser lens 8. Thereby, the depth of focus and resolution can 20 be controlled without the illumination efficiency being reduced and optimum annular illumination under an optimum σ value can be accomplished.

Of course, an excimer laser (KrF: 248 nm, ArF: 193 nm, etc.) may be used as the light source of the projection 25 exposure apparatus according to the present embodiment.

Also, in the embodiment shown in FIG. 1, the fly-eye lens 5 is used as the optical integrator, but this is not restrictive. For example, as shown in FIG. 10, a bar-like optical element 52 may be employed as the optical integrator. This bar-like 30 optical element 52 is constructed of glass formed into a bar-like shape, or is constructed such that the inner surface of a prismatic or cylindrical barrel is a reflecting surface. The parallel light beam from the mercury arc lamp 1 passed via the elliptical mirror 2, the reflecting mirror 3 and the 35 collimator lens 4 is condensed on the entrance surface of the bar-like optical element 52 by a lens 51 and repeats reflection on the inner surface of this bar-like optical element 52, thereby emerging from the bar-like optical element 52 with a uniform illumination distribution. This emergent light 40 forms a light source image on the aperture stop 6 by a lens 53 provided on the exit side of the bar-like optical element 52. Thereby, an annular secondary light source is formed on the aperture stop 6.

In the embodiment shown in FIG. 11, a prism member 45 such as a cone lens 54 of which the entrance side surface and the exit side surface are conical surfaces, as shown, for example, in FIG. 11, may be disposed in the optical path from the collimator lens 4 to the fly-eye lens 5. Thereby, the light beam entering the fly-eye lens 5 is made into a parallel 50 light beam of which the cross-sectional shape is annular, and an annular secondary light source is formed on the exit surface of the fly-eye lens 5. Thus, an annular secondary light source can be provided without involving a reduction in the efficiency of the quantity of light. 55

In the embodiment shown in FIG. 11, the cone lens 54 may be divided by a plane perpendicular to the optical axis. In other words, the cone lens 54 may be formed or replaced by two optical elements, one being an optical element whose light incident side (end) has a conically recessed surface and 60 whose light exit side (end) has a flat plane surface, and the other being an optical element which has a flat plane end surface at a light incident side and a conically projected end surface at a light exit side, and both of these elements being arranged between the collimator lens 4 and the fly-eye lens 65 5. Such an arrangement may form an annular secondary light source at a light exit plane of the fly-eye lens 5. By changing

a distance along the optical axis between those two optical elements, an annular ratio of the secondary light source formed on the exit plane of the fly-eye lens can be changed.

Further, in the embodiment shown in FIG. 11, design may be made such that the inner diameter and outer diameter of the aperture stop 6 are variable, and this aperture stop 6 may be disposed at any location which is conjugate with the position at which the secondary light source is formed. For example, it is also conceivable to dispose a stop of which the diameter of the opening portion is variable on the exit surface side of the fly-eye lens 5, dispose a stop of which the diameter of the light intercepting portion is variable at a location conjugate with the exit surface of the fly-eye lens, and vary the annular ratio and σ value of the annular secondary light source.

In the above described embodiments, the aperture stop may be formed by a transparent type liquid crystal display device, an electrochromic device or the like.

What is claimed is:

1. A projection exposure apparatus including:

illuminating optical means for illuminating a projection negative; and

projection optical means for projection-exposing said projection negative illuminated by said illuminating optical means onto a substrate;

said illuminating optical means including light source means for supplying exposure light, annular light source forming means for forming an annular secondary light source, which has a plurality of light source images, by the light from said light source means, and condenser means for condensing light from said annular light source forming means on said projection negative;

said apparatus satisfying the following condition:

$$\tfrac{1}{3} \leq d_1/d_2 \leq \tfrac{2}{3},$$

where d_1 is the inner diameter of said annular secondary light source, and d_2 is the outer diameter of said annular secondary light source;

said apparatus also satisfying the following condition:

$$0.45 \leq NA_2/NA_1 \leq 0.8,$$

where NA_1 is the numerical aperture of said projection optical means, and NA_2 is the numerical aperture of said illuminating optical means determined by the outer diameter of said annular secondary light source.

2. A projection exposure apparatus according to claim 1, wherein said annular light source forming means includes:

an optical integrator; and

stop means disposed in the optical path of light emerging from said optical integrator and having an annular opening portion.

3. A projection exposure apparatus according to claim 2, wherein said optical integrator is comprised of a plurality of lens elements.

4. A projection exposure apparatus according to claim 2, wherein said optical integrator includes a bar-like optical element.

5. A projection exposure apparatus according to claim 2, wherein said stop means has a plurality of opening portions differing in the ratio of the inner diameter of said annular opening portion to the outer diameter of said annular opening portion from one another, and one of said plurality of opening portions of said stop means is disposed in said optical path.

6. A projection exposure apparatus according to claim 5, wherein said stop means includes a circular opening portion.

7. A projection exposure apparatus according to claim 5, further including:

driving means for disposing one of said plurality of opening portions in said optical path;

input means for inputting information regarding various conditions during exposure; and

control means for controlling said driving means on the basis of the input information from said input means.

8. A projection exposure apparatus according to claim 7, wherein said input means includes detecting means for detecting a mark on said projection negative on which the information regarding the various conditions during exposure is recorded.

9. A projection exposure apparatus according to claim 1, wherein said projection optical means includes an aperture stop of which the diameter of the opening is variable, and said projection exposure apparatus further includes:

driving means for varying said diameter of the opening of said aperture stop;

input means for inputting information regarding various conditions during exposure; and

control means for controlling said driving means on the basis of the input information from said input means.

10. A projection exposure apparatus according to claim 1, wherein said annular light source forming means includes light guide means for transmitting said exposure light.

11. A projection exposure apparatus according to claim 10, wherein said light guide means is constructed such that the entrance side cross-sectional shape of said light guide means is circular and the exit side cross-sectional shape of said light guide means is annular.

12. A projection exposure apparatus including:

illumination optical means for illuminating a projection negative; and

projection optical means for projection-exposing said projection negative illuminated by said illumination optical means onto a substrate;

said illumination optical means including light source means for supplying exposure light, means for forming a secondary light source, which has a plurality of light source images, by the light from said light source means, means including annular ratio changing means for converting said secondary light source into an annular secondary light source and changing a ratio between an inner diameter and outer diameter of said annular secondary light source, and condenser means for condensing light from said annular secondary light source onto said projection negative,

said apparatus satisfying the following condition:

$$\tfrac{1}{3} \leq d_1/d_2 \leq \tfrac{2}{3}$$

where d_1 is the inner diameter of said annular secondary light source, and d_2 is the outer diameter of said annular secondary light source, and said apparatus satisfying the following condition:

$$0.45 \leq NA_2/NA_1 \leq 0.8$$

where NA_1 is the numerical aperture of said projection optical means, and NA_2 is the numerical aperture of said illumination optical means determined by the outer diameter of said annular secondary light source.

13. A projection exposure apparatus according to claim 12, wherein said means for forming said secondary light source has an optical integrator.

14. A projection exposure apparatus according to claim 13, wherein said annular ratio changing means includes stop means disposed in an optical path of light flux emergent from said optical integrator and having an annular opening portion.

15. A projection exposure apparatus according to claim 14, wherein said stop means includes a plurality of opening portions differing from one another in a ratio of inner diameter of said annular opening portion to outer diameter of said annular opening portion, and one of said plurality of opening portions of said stop means is disposed in the optical path of said illumination optical means.

16. A projection exposure apparatus according to claim 15, wherein said stop means includes a circular opening portion.

17. A projection exposure apparatus according to claim 15, further including:

driving means for disposing one of said plurality of opening portions in said optical path;

input means for inputting information regarding various conditions during exposure; and

control means for controlling said driving means on the basis of the input information from said input means.

18. A projection exposure apparatus according to claim 12, further including:

input means for inputting information regarding various conditions during exposure; and

control means for controlling said annular ratio changing means on the basis of the input information from said input means.

19. A projection exposure apparatus according to claim 18, wherein said annular ratio changing means includes a plurality of opening portions of which a ratio between an inner diameter and an outer diameter is different from one another, and one of said plurality of opening portions is disposed in an optical path of said illumination optical means.

20. A projection exposure apparatus according to claim 18, wherein said annular ratio changing means is disposed in an optical path of said illumination optical means and includes a movable stop for changing the ratio between the inner diameter and outer diameter.

21. A projection exposure apparatus comprising: an illuminating optical system; and

a projection optical system;

said illumination optical system including a light source, an optical integrator and a condenser optical system;

light from said light source passing through said optical integrator, said condenser optical system, a projection negative and said projection optical system, and onto a substrate;

said optical integrator forming a plurality of annular light source images; and

the following conditions being satisfied:

$$\tfrac{1}{3} \le d_1/d_2 \le \tfrac{2}{3}$$

$$0.45 \le NA_2/NA_1 \le 0.8$$

where d_1 is an inner diameter of said plurality of annular light source images, d_2 is an outer diameter of said plurality of annular light source images, NA_1 is the numerical aperture of said projection optical system at a side of said projection negative and NA_2 is the numerical aperture of said condenser optical system at

an exit side determined by the outer diameter of said plurality of annular light source images.

22. A projection exposure apparatus including:

an illumination optical system; and

a projection optical system;

said illumination optical system including a light source, an optical integrator, an annular stop and a condenser optical system;

light from said light source passing through said optical integrator, said condenser optical system, a projection negative and said projection optical system and onto a substrate;

said annular stop being provided at a position where a plurality of images are formed by said illumination optical system;

said apparatus satisfying the following conditions:

$$\tfrac{1}{2} \leq d_1/d_2 \leq \tfrac{2}{3}$$

$$0.45 \leq NA_2/NA_1 \leq 0.8$$

where d_1 is an inner diameter of an opening of said annular stop, d_2 is an outer diameter of the opening of said annular stop, NA_1 is the numerical aperture of said projection optical system at a side of said projection negative and NA_2 is the numerical aperture of said condenser optical system at an exit side determined by the outer diameter of the opening of said annular stop.

23. A projection exposure apparatus comprising:

an illuminating optical system; and

a projection optical system;

said illuminating optical system including a light source, an optical integrator, an annular stop and a condenser optical system;

light from said light source passing through said optical integrator, said condenser optical system, a projection negative and said projection optical system and onto a substrate;

said illuminating optical system forming a plurality of annular light source images satisfying the following condition:

$$\tfrac{1}{2} \leq d_1/d_2 \leq \tfrac{2}{3}$$

where d_1 is an inner diameter of said plurality of annular light source images and d_2 is an outer diameter of said plurality of annular light source images; and

said projection exposure apparatus satisfying the following condition:

$$0.45 \leq NA_2/NA_1 \leq 0.8,$$

where NA_1 is the numerical aperture of said projection optical system at a side of said projection negative, and NA_2 is the numerical aperture of said condenser optical system at an exit side determined by an outer diameter of an opening of said annular stop.

24. A projection exposure apparatus comprising:

an illuminating optical system; and

a projection optical system;

said illuminating optical system including a light source, an optical integrator and a condenser optical system;

light from said light source passing through said optical integrator, said condenser optical system, a projection negative and said projection optical system and onto a substrate;

said illuminating optical system forming a plurality of annular light source images satisfying the following condition:

$$\tfrac{1}{3} \leq d_1/d_2 \leq \tfrac{2}{3},$$

where d_1 is an inner diameter of said plurality of annular light source images, d_2 is an outer diameter of said plurality of annular light source images;

the ratio between the inner diameter and the outer diameter of said annular light source images being variable within the range of said condition;

said projection exposure apparatus satisfying the following condition:

$$0.45 \leq NA_2/NA_1 \leq 0.8,$$

where NA_1 is the numerical aperture of said projection optical system at a side of said projection negative, and NA_2 is the numerical aperture of said condenser optical system at an exit side determined by the outer diameter of said plurality of annular light source images.

25. A projection exposure apparatus comprising:

an illuminating optical system; and

a projection optical system;

said illuminating optical system including a light source, an optical integrator, a first annular stop, a second annular stop and a condenser optical system;

light from said light source passing through said optical integrator, said condenser optical system, a projection negative and said projection optical system and onto a substrate;

said first and second annular stops satisfying the following condition:

$$\tfrac{1}{3} \leq d_1/d_2 \leq \tfrac{2}{3},$$

where d_1 is an inner diameter of an opening of said annular stops and d_2 is an outer diameter of an opening of said annular stops;

said first and second annular stops being selectively disposed in a position where a plurality of light source images are formed by said illuminating optical system; and

said projection exposure apparatus satisfying the following condition:

$$0.45 \leq NA_2/NA_1 \leq 0.8,$$

where NA_1 is the numerical aperture of said projection optical system at a side of said projection negative, and NA_2 is the numerical aperture of said condenser optical system at an exit side determined by the outer diameter of said plurality of annular light source images.

* * * * *

1 26. A projection exposure apparatus comprising:

2   an illumination optical system including an optical

3 integrator that forms a substantially annular secondary

4 light source; and

5   a projection optical system,

6   said illumination optical system satisfying the

7 following condition:

8          $1/3 \leq d_1/d_2 \leq 2/3$

9   wherein d_1 is an inner diameter of the secondary light

10 source and d_2 is an outer diameter of the secondary light

11 source.

1 27. A projection exposure apparatus comprising:

2   an illumination optical system including an optical

3 integrator through which a light beam irradiated on a mask

4 passes; and

5   a projection optical system;

6   said illumination optical system providing an intensity

7 distribution of the light beam with an annular increased

8 intensity portion relative to the inside thereof, and

9   said illumination optical system satisfying the

10 following condition:

11          $0.45 \leq NA_2/NA_1 \leq 0.8$

12   wherein NA_1 is the numerical aperture of said

13 projection optical system, and NA_2 is the numerical aperture

14 of light from the increased intensity portion.

13

1   28. A projection exposure apparatus comprising:

2   an illumination optical system including an optical

3   integrator through which a light beam irradiated on a mask

4   passes; and

5   a projection optical system;

6   said illumination optical system providing an intensity

7   distribution of the light beam with an annular increased

8   intensity portion relative to the inside thereof and

9   changing the intensity distribution in accordance with a

10   pattern formed on the mask so as to maintain a shape of the

11   annular increased intensity portion.

1   29. A projection exposure apparatus comprising:

2   an illumination optical system disposed between a light

3   source and a mask;

4   a projection optical system disposed between the mask

5   and a substrate; and

6   an optical device, disposed within the illumination

7   optical system, that forms a plurality of secondary light

8   sources including a substantially annular secondary light

9   source and a substantially circular secondary light source

10   with light from the light source to illuminate the mask with

11   light from one of the plurality of secondary light sources,

12   the optical device changing an intensity distribution of the

13   annular secondary light source so as not to change the shape

14   thereof and changing an intensity distribution of the

14

15   circular secondary light source so as not to change the

16   shape thereof.

1   30.   A combination of an illuminator and a

2   photolithographic projection imager, the combination

3   comprising:

4   a.   an illuminator optical system for directing

5   illumination from a source to a pupil of the illuminator

6   from which a reticle is illuminated to be imaged on a wafer

7   by an objective imaging system;

8   b.   the illuminator in a collimated region of

9   illumination upstream of the illuminator pupil having a pair

10 of refractive elements having conical surfaces that are

11 respectively concave and convex;

12   c.   said elements being arranged so that an upstream

13 one of said elements diverges the illumination into a single

14 beam having an annular configuration of intensity and a

15 downstream one of said elements counters the divergence

16 caused by the upstream element to give the illumination an

17 annular intensity profile of the single beam at the pupil of

18 the illuminator; and

19   d.   a uniformizer arranged between said elements and

20 the pupil of the illuminator.

1   31.   The combination of Claim 30, wherein the distance

2   between said elements is variable to vary the radius of said

3   annular intensity profile.

1   32.   The combination of Claim 31, wherein said distance

2   between said elements can be reduced enough to counter said

3   divergence approximately at its source to keep said

4   intensity configuration from becoming annular.

1   33.   The combination of Claim 30, wherein said upstream

2   element has said concave conical surface and said downstream

3   element has said convex conical surface.

1   34.   The combination of Claim 30, wherein a mask is

2   positionable at said pupil within said annular intensity

3   profile.

1   35.   The combination of Claim 30, wherein said concave

2   and convex conical surfaces have the same conic angle.

1   36.   The combination of Claim 30, wherein said elements

2   are separated by an air gap.

1   37.   The combination of Claim 30, wherein said conical

2   surfaces are arranged to confront each other.

1   38.   The combination of Claim 37, wherein the distance

2   between said elements is variable to vary the radius of said

3   annular intensity profile to accommodate characteristics of

4   the reticle.

1   39.   The combination of Claim 38, wherein said conical

2   surfaces can be moved into proximity for countering said

3   divergence to keep said intensity configuration from

4   becoming annular.

1   40.   The combination of Claim 39, wherein a mask of

2   variable size is positionable downstream of said conical

3   surfaces within said annular intensity profile.

1   41.   The combination of Claim 30, wherein said

2   refractive elements are faceted.

1   42.   In an illuminator for a photolithographic

2   projection imager, the improvement comprising:

3   a.   a first refractive element arranged in a collimated

4   region of an illumination path of said illuminator upstream

5   of a pupil of said illuminator so that a conical surface of

6   said first refractive element diverges the illumination into

7   a single beam having an annular configuration of intensity;

8   b.   a second refractive element arranged to receive

9   diverged illumination from said first refractive element and

10 said second refractive element having a conical surface

11 arranged for countering the illumination divergence caused

12 by said first refractive element to fix the radius of the

13 divergence of the single beam of said illumination;

14   c.   the radius of divergence of the illumination output

15 from the second refractive element appearing as an annular

16 intensity profile of illumination at the pupil region of the

17 illuminator causing illumination with an annular intensity

18

18 profile to illuminate a reticle that is imaged onto a wafer

19 by an objective imaging system of the photolithographic

20 projection imager; and

21   d. a uniformizer arranged between said first and

22 second refractive elements and the pupil of the illuminator.

1   43. The improvement of Claim 42, wherein said conical

2 surface of said first refractive element is concave, and

3 said conical surface of said second refractive element is

4 convex.

1   44. The improvement of Claim 42, wherein said first

2 and second refractive elements are separated by an air gap.

1   45. The improvement of Claim 42, wherein a distance

2 between said refractive elements is variable for varying

3 said radius of illumination divergence to accommodate

4 characteristics of the reticle.

1   46. The improvement of Claim 45, wherein a minimum of

2 said variable distance between said refractive elements

3 results in said second element countering the illumination

4 divergence so that the configuration of illumination

5 intensity does not become annular.

1   47. The improvement of Claim 45, including a variable

2   size mask arranged for blocking illumination within said

3   annular configuration of intensity.

1   48. The improvement of Claim 42, wherein said conic

2   surfaces of said first and second refractive elements have

3   the same conic angle.

1   49. The improvement of Claim 42, wherein said conic

2   surface of said first and second refractive elements

3   confront each other.

1   50. The improvement of Claim 49, wherein a distance

2   between said refractive element is variable for varying said

3   radius of illumination divergence to accommodate

4   characteristics of the reticle.

1   51. The improvement of Claim 50, wherein said

2   illumination divergence is substantially eliminated by

3   moving said conic surfaces into proximity.

1   52. The improvement of Claim 50, wherein illumination

2   within said annular configuration of intensity is blocked by

3   a mask.

1   53. The improvement of Claim 42, wherein said conic

2   surfaces of said first and second refractive elements face

3   away from each other.

1   54. The improvement of Claim 42, wherein said

2   refractive elements are faceted.

1   55. An illuminator combined with a photolithographic

2   projection imager, the combination comprising:

3   a. the illuminator having an optical system for

4   directing illumination along an optical axis of the

5   illuminator upstream of a pupil of the illuminator so that

6   an intensity profile of the illumination as the illuminator

7   pupil is directed to a reticle that is imaged on a wafer by

8   an objective imaging system of the photolithographic

9   projection imager;

10   b. a diverging element arranged in a collimated region

11   of the illumination path of said illuminator upstream of the

12   illuminator pupil for diverging said illumination into a

13   single beam having an annular configuration of intensity;

14   c. a counter diverging element arranged in said

15   illumination path at a variable distance from said diverging

16   element for receiving said diverging illumination;

17   d. said counter diverging element being arranged for

18   countering the divergence of said illumination and fixing

19   the radius of said annular configuration of intensity of the

20 single beam as a function of the distance between said

21 elements;

22   e. the annular configuration of illumination intensity

23 output from the counter diverging element appearing as an

24 annular intensity profile of the single beam of the

25 illumination at the illuminator pupil and at the reticle so

26 that the radius of the annular intensity profile

27 accommodates characteristics of the reticle; and

28   f. a uniformizer arranged between said elements and

29 the pupil of the illuminator.

1   56. The combination of Claim 55, wherein said elements

2 are refractive and have faceted surfaces.

1   57. The combination of Claim 55, wherein said elements

2 are concentrically diffractive.

1   58. The combination of Claim 55, wherein said elements

2 are reflective and have conical surfaces.

1   59. The combination of Claim 55, wherein said elements

2 are refractive and have conical surfaces.

1   60. The combination of Claim 59, wherein said conical

2 surfaces are concave on one of said elements and convex on

3 another of said elements.

1   61. The combination of Claim 60, wherein said concave

2 and convex conical surfaces confront each other.

1   62. The combination of Claim 61, wherein said counter

2 diverging element can be positioned for countering said

3 diverging illumination so that the illumination intensity

4 profile does not become annular.

1   63. The combination of Claim 60, wherein said concave

2 and convex conical surfaces face away from each other.

1   64. The combination of Claim 55, wherein said

2 diverging element is refractive and has a concave conical

3 surface.

1   65. The combination of Claim 55, wherein said counter

2 diverging element is refractive and has a convex conical

3 surface.

1   66. The combination of Claim 55, wherein said counter

2 diverging element can be positioned for countering said

3 diverging illumination so that said intensity configuration

4 does not become annular.

1   67. The combination of Claim 55, including a variable

2 size mask positioned to block illumination within said

3 annular configuration.

1   --68. An illuminator for a photolithographic

2 projection imager including a variable annular illumination

3 intensity profiler, said profiler comprising a pair of

4 diverging and counter diverging elements arranged in the

5 illumination path of said illuminator so that said diverging

6 element diverges the illumination into an annular

7 configuration of intensity and said counter diverging

8 element counters the divergence caused by said diverging

9 element to give the illumination an annular intensity

10 profile the configuration of which is a function of the

11 distance between the pair of elements.--

1   --69. An illuminator according to Claim 68, wherein

2 the diverging element is a refractive element having a

3 concave conical surface and the counter diverging element is

4 a refractive element having a convex conical surface.--

1   --70. An illuminator according to Claim 68, wherein

2 the diverging and counter diverging elements are refractive

3 elements that are faceted.--

1   --71. An illuminator according to Claim 68, wherein

2 said diverging and counter diverging elements are

3 concentrically diffractive.--

1   --72.   An illuminator according to Claim 68, wherein

2   the diverging and counter diverging elements are reflective

3   and have conical surfaces.--

1   --73.   An illuminator according to Claim 68, wherein

2   the diverging element is a first refractive element arranged

3   in the illumination path of the illumination upstream of a

4   pupil region of said illuminator so that a conical surface

5   of said first refractive element diverges the illumination

6   into an annular configuration of intensity, and said counter

7   diverging element is a second refractive element arranged to

8   receive diverged illumination from said first refractive

9   element, said second refractive element having a conical

10   surface arrangeable for countering the illumination

11   divergence caused by said first refractive element and

12   fixing the radius of the divergence of said illumination.--

1   --74.   An illuminator according to any of Claims 68 to

2   73, wherein the distance between the diverging and counter

3   diverging elements is variable to vary the radius of the

4   annular intensity profile.--

1   --75.   An illuminator according to any of Claims 68 to

2   73, wherein the distance between the diverging and counter

3   diverging elements can be reduced enough to counter said

4   divergence approximately at its source to keep the intensity

5   configuration from becoming annular.--

--76. An illuminator according to any of Claims 68-73, wherein the diverging and counter diverging elements are arranged on the optical axis of the illuminator upstream of a pupil region of said illuminator.--

--77. An illuminator according to Claim 76, wherein a mask is positioned at the pupil region within the annular intensity profile.--

--78. An illuminator according to any of Claims 68 to 73, wherein the diverging and counter diverging elements are separated by an air gap.--

--79. An illuminator according to Claim 69 or 73, wherein the concave and convex conical surfaces have the same conic angle.--

--80. An illuminator according to Claim 69 or 73, wherein the conical surfaces are arranged to confront each other.--

--81. An illuminator according to Claim 69 or 73, wherein the conical surfaces can be moved into proximity for countering the divergence to keep the intensity configuration from becoming annular.--

1   --82. An illuminator according to Claim 69 or 73,

2   wherein a mask of variable size is positioned downstream of

3   said conical surfaces within said annular intensity

4   profile.--

1   --83. An illuminator according to Claim 73, wherein

2   the conical surface of the first refractive element is

3   concave, and the conical surface of the second refractive

4   element is convex.--

1   --84. An illuminator according to any of Claims 68-73

2   or 83, wherein a variable size mask is arranged within the

3   illumination path for blocking illumination within the

4   annular configuration of intensity.--

1   --85. An illuminator according to Claim 84, wherein

2   said illumination divergence is substantially eliminated by

3   moving said conic surfaces into proximity.--

1   --86. An illuminator according to any of Claims 68-73,

2   wherein the illumination within said annular configuration

3   of intensity is blocked by a mask.--

1   --87. An illuminator according to Claim 69 or 73,

2   wherein the conic surfaces of the refractive elements face

3   away from each other.--

1   --88. An illuminator according to Claim 73, wherein

2   the refractive elements are faceted.--

1   --89. An illuminator according to Claim 79, wherein

2   the concave and convex conical surfaces face away from each

3   other.--

1   --90. An illuminator according to Claim 68 or 69,

2   wherein a variable size mask is positioned within said

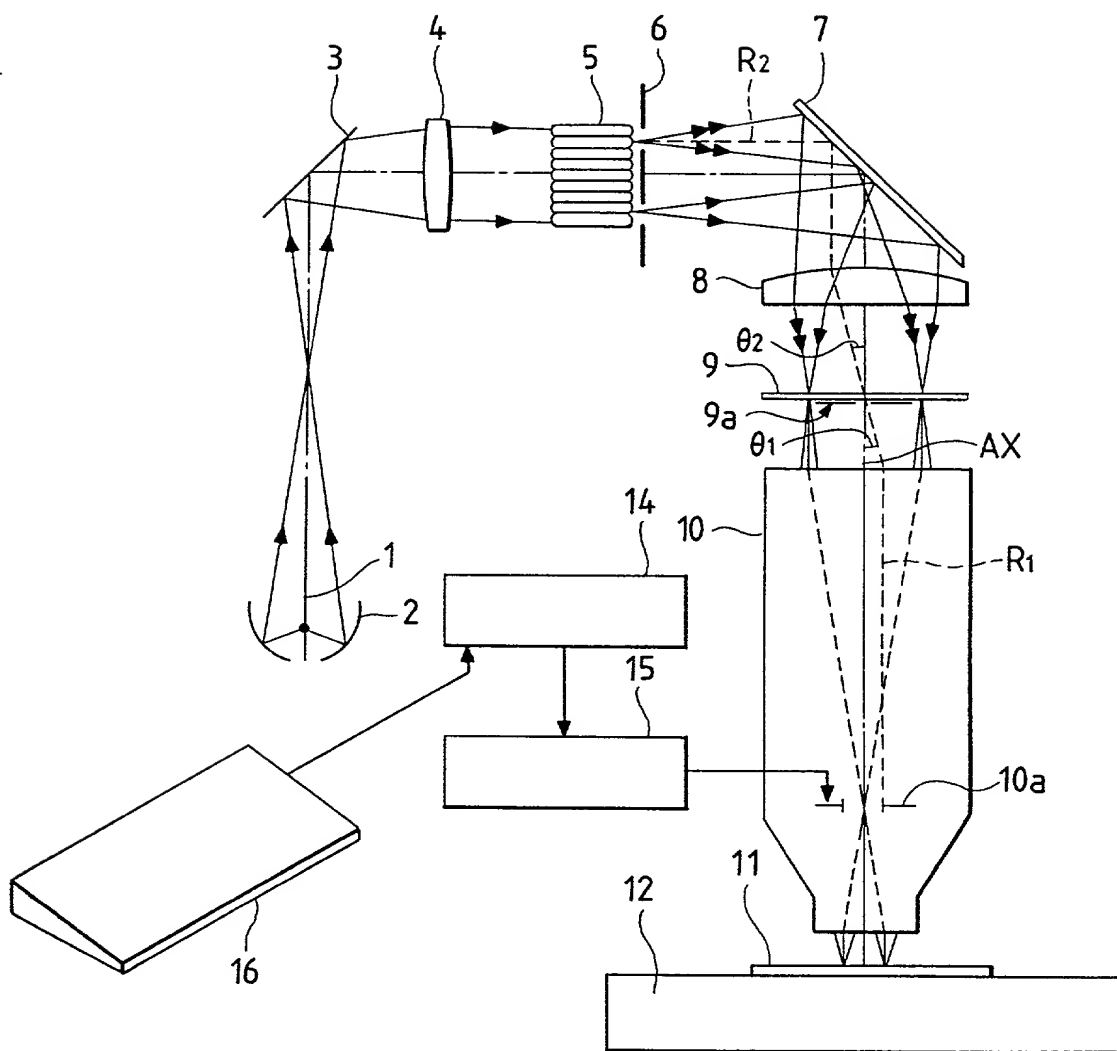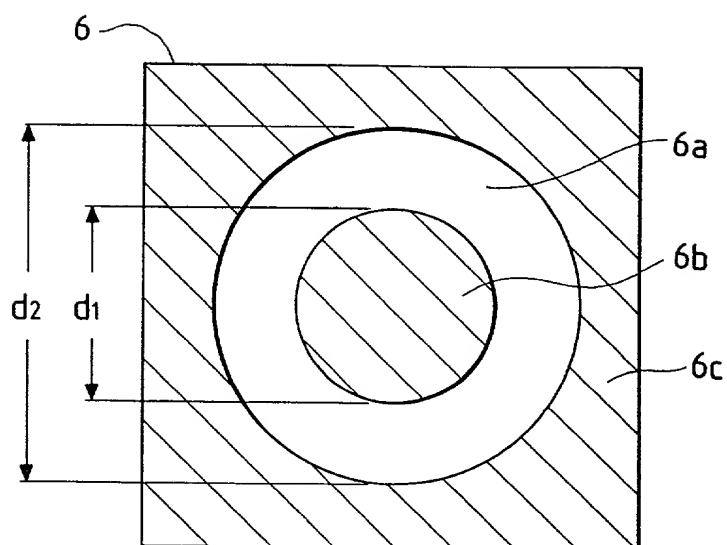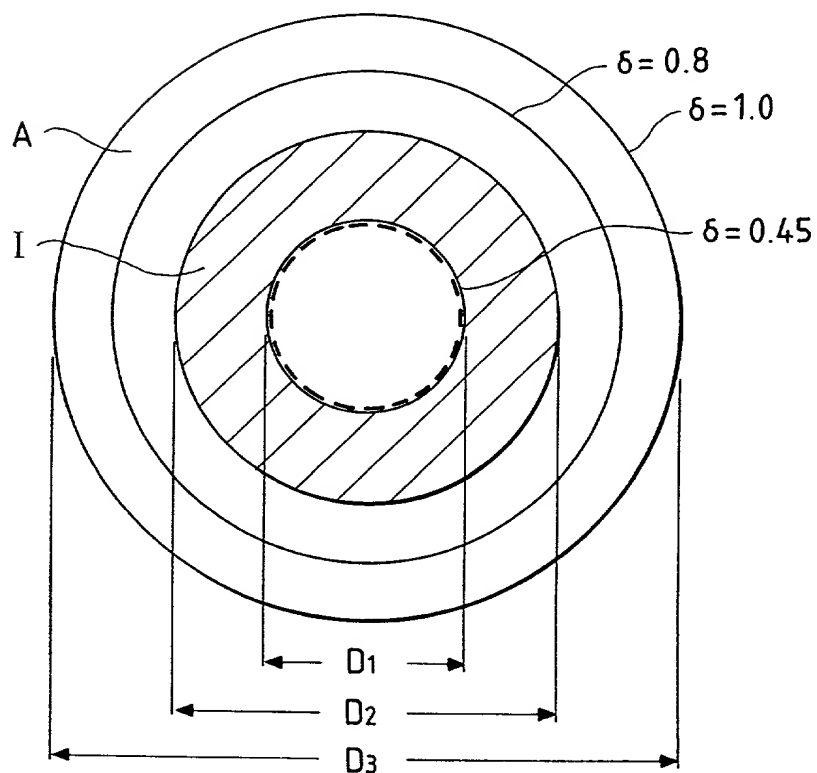3   illuminator to block illumination within said annular

4   configuration.--

FIG. 1
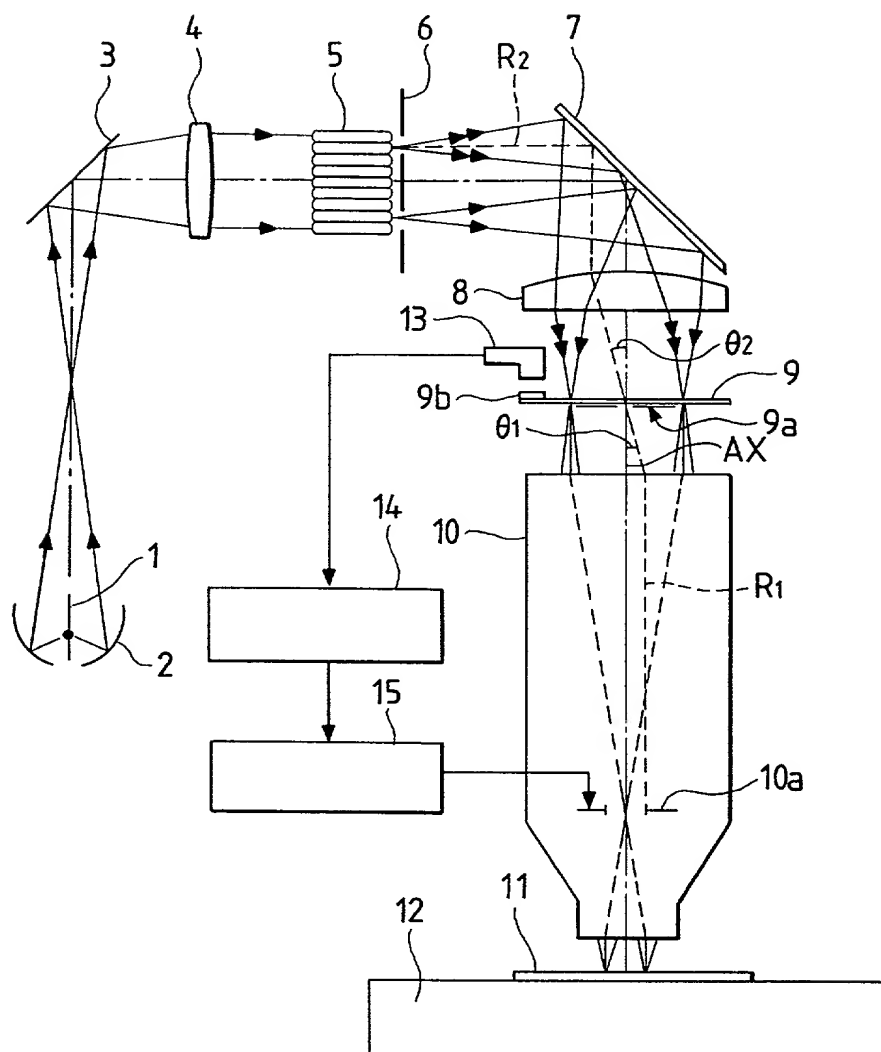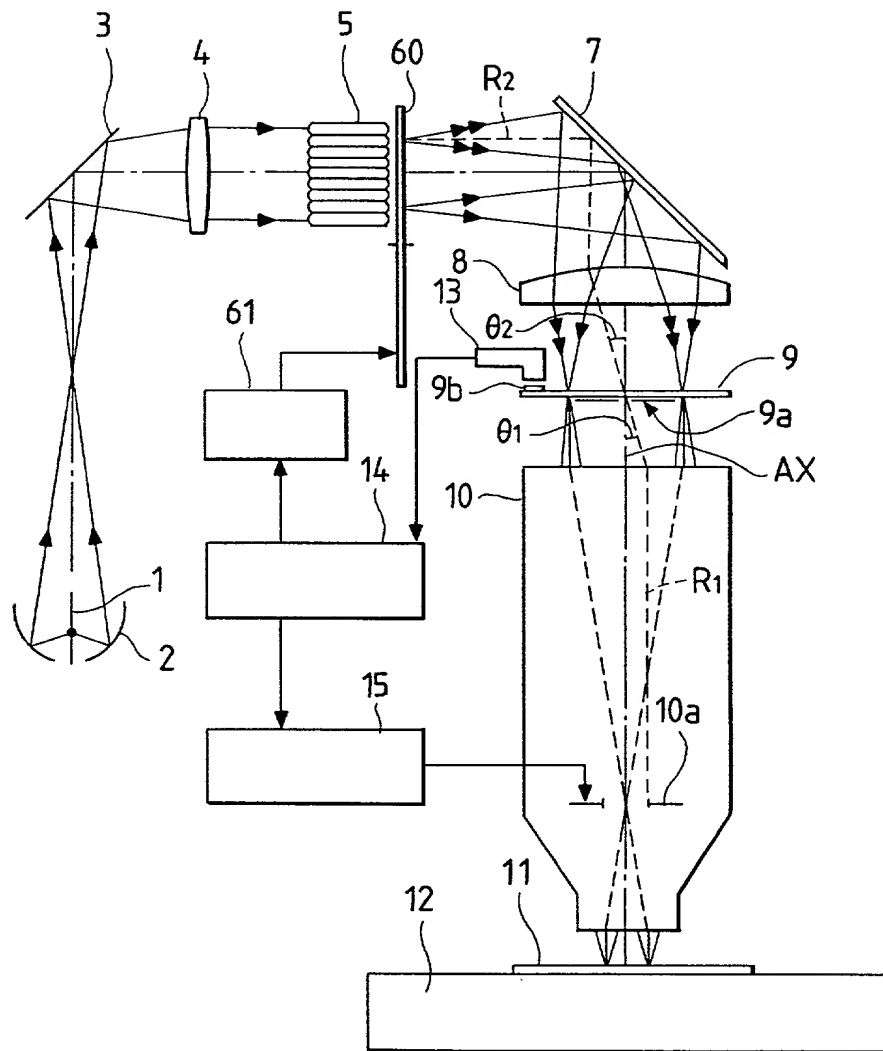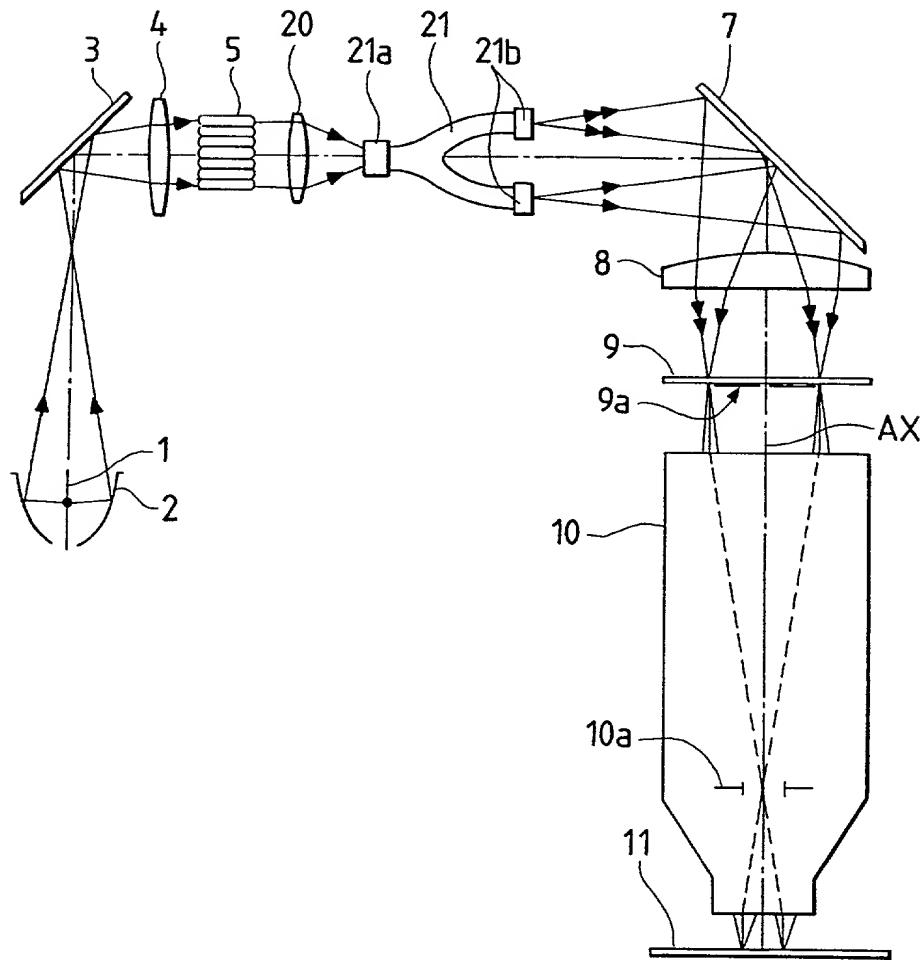
FIG. 2

6

6a

6b

6c

d_2 d_1

FIG. 3

δ = 0.8

δ = 1.0

δ = 0.45

A

I

D_1

D_2

D_3

FIG. 4

FIG. 5

FIG. 6

FIG. 7

FIG. 8

FIG. 9

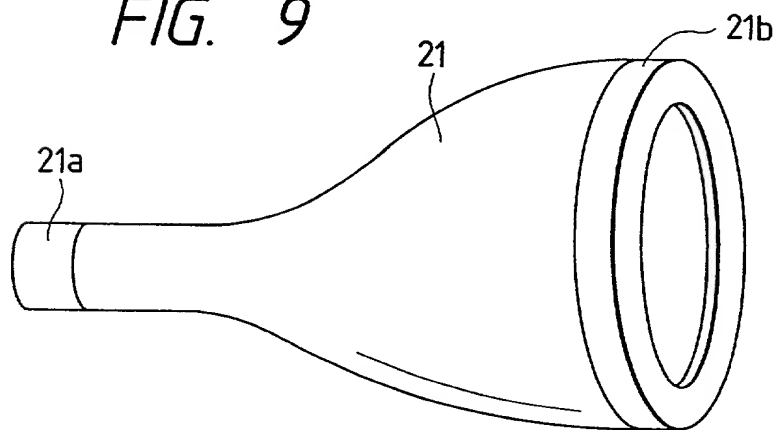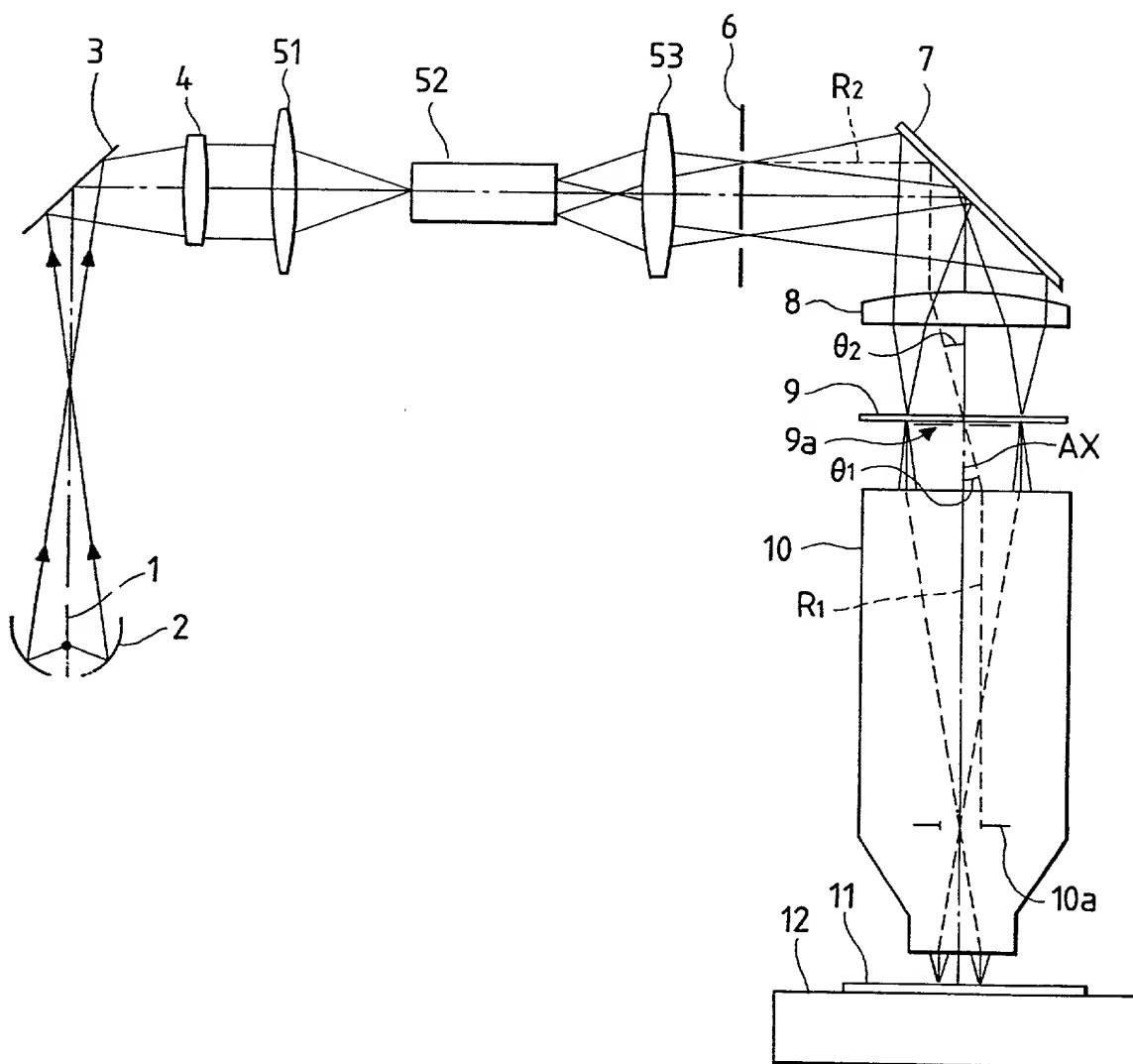# FIG. 10

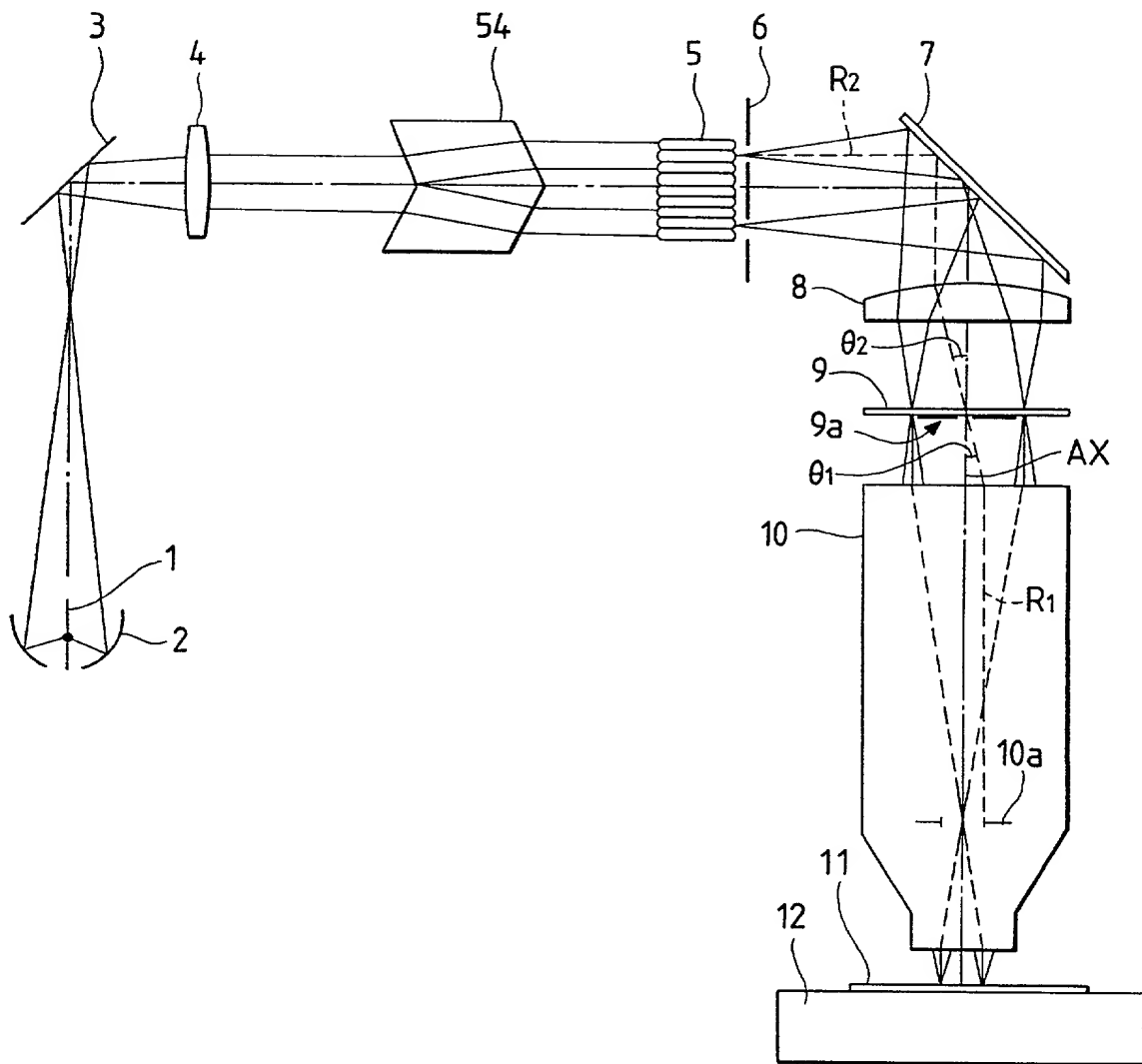# FIG. 11

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

In re the application of:

Kazuo USHIDA et al.

Appln. No. 09/103,536

Filed: June 24, 1998

For: PROJECTION EXPOSURE APPARATUS

*   *   *

DECLARATION IN SUPPORT OF REISSUE APPLICATION

We, Kazuo Ushida and Masaomi Kameyama, hereby make the following Declaration:

1) We are citizens of Japan residing at Tokyo, Japan.

2) We verily believe that we are the original, first, and joint inventors of the invention described and claimed in United States Letters Patent No. 5,530,518 issued June 25, 1996, and in the specification and claims of the above-identified reissue application.

3) We have reviewed and understand the contents of the specification and claims of said application.

4) We acknowledge the duty to disclose information that we are aware of which is material to patentability as defined in 37 C.F.R. § 1.56.

5) We hereby claim foreign priority benefits under Title 35, U.S.C. § 119 with respect to Japanese Patent Application No. 3-343601 filed December 25, 1991, the

priority of which was also claimed in our original application for patent.

6) We verily believe said Letters Patent to be partly inoperative by reason of our having claimed less than we had a right to claim in said Letters Patent, and more particularly by our having omitted therefrom claims of the scope of Claims 26-29 presented in this reissue application.

7) The failure to present, in our original application, claims of the scope of Claims 26-29 of our reissue application constitutes an error that arose without any deceptive intention on our part or on the part of Nikon Corporation, the Assignee of said Letters Patent.

The undersigned declare further that all statements made herein of their own knowledge are true and that all statements made on information and belief are believed to be true; and further that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under Section 1001 of Title 18 of the United States Code and that such willful false statements may jeopardize the validity of the application or any patent issuing thereon.

(month) (day)
8/11/1998
Date

Kazuo Ushida
Kazuo Ushida

August 18, 1998
Date

Masaomi Kameyama
Masaomi Kameyama

NHS:lmb

2

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

In re the application of:

Kazuo USHIDA et al.

Appln No.: 09/103,536

Filed: June 24, 1998

For: PROJECTION EXPOSURE APPARATUS

*   *   *

OFFER TO SURRENDER, ASSENT OF
ASSIGNEE AND POWER OF ATTORNEY

Nikon Corporation, a corporation duly organized under

the laws of Japan and having a place of business at Tokyo,

Japan, is owner, by assignment, of the entire title to

United States Letters Patent No. 5,530,518 granted on June

25, 1996, for PROJECTION EXPOSURE APPARATUS.

Nikon Corporation hereby offers to surrender said

Letters Patent and assents to the reissue of said Letters

Patent.

Nikon Corporation hereby appoints Nelson H. Shapiro,

Registration No. 17,095, Mitchell W. Shapiro, Registration

No. 31,568, and James T. Wilson, Registration No. 41,439, of

the firm of Shapiro and Shapiro, Registration No. 18,810,

1

its attorney(s) and/or agent(s) with full power of
substitution and revocation, to prosecute this application
and to transact all business in the Patent and Trademark
Office connected therewith, all correspondence to be
addressed to Shapiro and Shapiro, 1100 Wilson Boulevard,
Suite 1701, Arlington, Virginia 22209.

NIKON CORPORATION

By: _____
    Signature

Name: Tadao TSURUTA

Title: Executive Vice President

Date: Aug. 18, 1998

2

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

In re the application of:

Kazuo USHIDA et al.

Appln. No. 09/103,536

Filed: June 24, 1998

For: PROJECTION EXPOSURE APPARATUS

*   *   *

STATEMENT UNDER 37 C.F.R. § 3.73(b)

Assistant Commissioner for Patents
Washington, D.C. 20231

Sir:

Nikon Corporation, a corporation duly organized under the laws of Japan, certifies that it is the Assignee of the above-identified patent application by virtue of an Assignment from the inventors of said patent application, said Assignment having been recorded in the Patent and Trademark Office at Reel 6350, Frame 0908.

The undersigned is authorized to sign this Statement on behalf of said Assignee.

September 11, 1998   By: _____
                                          Nelson H. Shapiro
                                          Reg. No. 17,095
                                          Attorney for Assignee